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A TREATISE

ON THE

PHYSIOLOGICAL ANATOMY OF THE LUNGS.

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"A TREATISE ON VITAL CAUSES," ETC.

LONDON:
JOHN CHURCHILL, NEW BURLINGTON STREET.
M DCCC LXII.

~~150. a. 53.~~
~~157. a. 246.~~

LONDON:
SAVILL AND EDWARDS, PRINTERS,
CHANDOS STREET.

BIBLIOTHECA · BODLEIANA

PHYSIOLOGICAL ANATOMY OF THE LUNGS.

INTRODUCTION.

It has been already demonstrated with more than sufficient clearness in former publications, by the author of the following pages, that every organ of the body is GALVANIZED into its vital activity, through the instrumentality of the atmospheric oxygen, acting upon the blood in the lungs. Hitherto it had been assumed by *some* writers, that the various vital combinations were attributable to an invisible fluid, *resident in the nervous system*; by *others* it was contended that they depended upon a vague "something," to which they gave the name of the function of "nutrition," which was supposed to be influenced by a "principle" of vitality, *resident in the various cytoblasts*, which occupy different stations or localities in the body.

The word "nutrition" was used as a kind of diminutive, implying a resemblance to that process whereby infants are suckled; and it was supposed that the cytoblasts were bribed to do their work, by each sort of nucleated cell having its peculiar tastes gratified. This theory may be called the doctrine of "choice," or "secondary assimilation."

Each of these hypotheses has given way to, or been entertained in conjunction with, one another, or with others still more impossible and contradictory.

There has, however, prevailed among them one, and only one, consistency—viz., that they have, one and all, concurred in ignoring the function of "breathing," as possessing any physiological significance or importance whatever.

Physiological writers did not indeed deny that the organs by which respiration was performed might occasionally be useful appendages to vocalists and professional lecturers, who might have the opportunity of turning them to pecuniary profit; and they were even willing to admit that they might sometimes be employed advantageously in "aërating" some of the fluids of the body, after the fashion of the makers of soda-water: but they never took the trouble to investigate what particular purpose the aërating of the fluids was calculated to accomplish, nor whether it had *any* purpose, further than that of bottling up a certain amount of oxygen, for some future use in some undefined part of the body. When and where it was destined to be employed was considered as constituting a question wholly distinct and apart from that relating to the function of breathing.

Practical writers were disposed to consider the lungs as capricious organs, incessantly prone to give trouble, by an over-zealous discharge of their function of "nutrition," and thereby running, and sometimes galloping, into a "consumption." And so far from viewing the lungs as constituting any essential part of the body, without the aid of which no single function could be discharged, the majority would doubtless have voted them to be a very inconvenient appendix, which it would be a great triumph of "surgery" to get rid of altogether, provided persons could afterwards do their talking by the aid of some mechanical substitute.

These views respecting the merely local nature of the respiratory operations have been already controverted by the author, and the true purposes of the lungs and the manner in which they discharge their functions have been dilated upon in former publications at sufficient length; and it has been thereby abundantly proved, and (it is believed) the facts are now universally acknowledged by the tacit, though somewhat ungenerous, acquiescence of physiologists, viz., that the respiratory changes constitute the exciting cause of all the vital operations throughout the body, and establish the link of connexion which binds together all the functions of animal existence.

Repudiating, then, the idea that the function of respiration is a process belonging exclusively to the lungs, or that it can be fully understood by merely studying the shape and structure of those organs, it follows that the investigation of all the points comprised in that process would involve neither more nor less than an inquiry into the *modus operandi* of physiological operations of every sort and kind.

It is obvious, however, that the points contained in the few following pages do not embrace so wide a scope. The object is simply to condense, into as small a compass as possible, those observations respecting the actual anatomical structure of the lungs (as far as *that* relates to their physiological performances), wherein a series of observations, extended over a period of many years, enables the author confidently to declare that the accounts which have hitherto prevailed are inaccurate, and to bring forward fresh anatomical facts, which his own researches have enabled him to verify.

With the view of circumscribing what he has himself to communicate into the smallest possible bulk, he has omitted all the known and undisputed facts that have been advanced by others.

In following out these intentions, he has been obliged to assume that his readers have a competent knowledge of those anatomical outlines concerning which there is no dispute, and which are to be found in all elementary anatomical treatises.

The object of the present work must not be looked upon as an attempt to comprise a detailed account of all matters directly and indirectly connected with the function of breathing, nor as pretending to supersede many valuable essays which have been already written on the subject, particularly such as relate to the shape, the position, and the relations (as to the locality of other organs), which belong to the lungs, nor as having a tendency to undervalue such publications as describe in full detail the particular muscles, and their modes of action, which are engaged in the mechanical movements occasioned by the act of breathing, and the particular nerves to whose influence those muscles owe allegiance.

In investigating the physiological anatomy of the lungs, it is convenient to make a cursory examination of the external and general features of those organs, before entering upon the consideration of their minute structure.

First, as regards the Pleura.

The pleura.

The general characteristics of this structure, and the mode in which it is spread out, so as to enclose and protect the lungs, and to render them

Blood-vessels.

detached and insulated from other organs, may be inferred with sufficient accuracy from the descriptions given in ordinary anatomical works. Two remarkable circumstances must, however, be noticed: viz., that the blood-vessels which are actually distributed to the tissue of the pleura, are exclusively derived from the pulmonary system of blood-vessels. (Vide Plate No. I., fig. *a* and fig. *b*.) This fact will establish the truth, that the function which the pleura is called upon to discharge is wholly and exclusively connected with the process of "respiration," since the evidences which this paper will bring to notice establish very convincingly that the pulmonary vessels are engaged exclusively in the respiratory process, and that the bronchial vessels fulfil the purpose of restoring

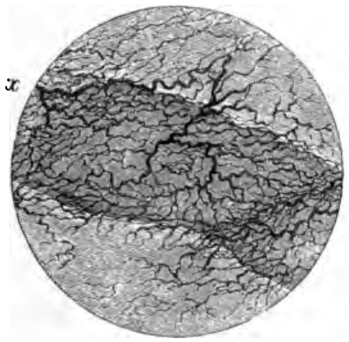


PLATE No. I., fig. *a*, represents a portion of the pleura, showing capillary vessels injected from the pulmonary artery. The part shaded dark, *x*, shows a longitudinal channel. (Magnified 20 diameters.)

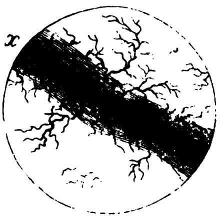


Fig. *b*. The same, magnified 10 diameters.

the tissue of the lungs, and their appendages, without any assistance or anastomosis from the pulmonary vessels.

Longitudinal channels.

The second point to be observed, in connexion with the pleura, consists in the fact, that certain longitudinal channels of a remarkable character exist in it. (*Vide* Plate No. I., fig. *a* and fig. *b*.) These channels somewhat resemble the sinuses in the dura mater of the brain; but they differ from them in the circumstance that they are quite colourless and transparent, and that if they transmit any fluid through them, that also is destitute of colour.

The largest of these longitudinal channels are to be found at the reflections of the pleura over the acute margins of the lobes.

They can be distended by inflating a recent lung. In one in which the pulmonary vessels have been injected, the gradual distension of the longitudinal channels, and their subsequent contraction when the air is again allowed to escape, can be easily demonstrated.

Tubular passages.

These channels are in connexion, by means of certain tubular passages running through the sub-pleural cellular tissue, with a number of foramina, which may be seen on the surface of the lungs and upon the interlobular surfaces also. These foramina, however, can only be seen when the pleura and sub-pleural cellular tissue have been stripped off from the surface of the

Foramina.

lungs, and they are always situated in the sulcus, which separates the minute leaflets (which constitute the ultimate pulmonary tissue) from one another, and are never found in the substance of a leaflet, except in the form of exceedingly minute orifices, discernible only by the microscope.

These foramina, if examined by the microscope, will be found to be the open extremities of minute bronchial tubes: it would be a great mistake, however, to suppose that a considerable number, comparatively, of the bronchial tubes terminate thus by open mouths on the surface of the lungs and of the lobules. The great majority of the terminal bronchial tubes end by plunging into the leaflets, but some of them make their appearance on the outer and on the interlobular surfaces in the manner described, studding these surfaces at tolerably regular intervals with foramina; and these foramina are in communication, by means of the tubular passages in the subpleural cellular tissue, with the longitudinal channels which are found in the substance of the pleura. The blood-vessels, derived from the pulmonary arteries and veins which ramify in the pleura, are almost entirely distributed around the walls of these longitudinal channels.

Without doubt, these longitudinal channels are rudimental representatives of the air-channels which exist in the long bones of birds. Whether those channels in the pleura transmit air only, or whether they transmit bronchial mucus, or whether they are in some way connected with the lymphatic system, may perhaps be a matter of doubt; but it seems abundantly evident that the function they discharge belongs exclusively to the process of respiration, since the fact that they derive their blood from the pulmonary system, and not from the bronchial vessels, tends to establish that point with great certainty.

Costal pleura.

The costal pleura, in like manner, derives its supply of blood from the pulmonary blood-vessels. About eight or ten arteries of considerable size, and about twelve or sixteen corresponding veins of some magnitude, cross behind that fold of the pleura which is sometimes called the broad ligament, to reach the thoracic pleura, and to become distributed upon it, imparting, therefore, to that structure also properties auxiliary to the process of respiration.

Sub-pleural cellular tissue.

Immediately beneath the pleura, and firmly adherent to it, is the sub-pleural cellular tissue, which may be separated into numerous layers, each of which is spread out from the successive divisions of the bronchial tubes; each layer being furnished with its special allotment of capillary blood-vessels, given off from certain arteries, derived from the aorta, which are usually distinguished by the name of "bronchial" arteries. But as this term serves to perpetuate an erroneous view of the destinations and purposes of these arteries, the author prefers to call them the "sustinent" arteries. Although these "sustinent" arteries are very minutely distributed over the successive layers of cellular tissue, they cannot be made visible in the pleura itself. This structure must therefore be looked upon as a product or secretion of the cellular tissue immediately beneath it, because it is impossible to suppose that its fabric is repaired by those branches of the pulmonary artery which alone are found to ramify within it, since those vessels are only adapted to accomplish the respiratory functions. **False membranes.** But when false membranes have become deposited in the surface of the pleura, it will be seen that the "sustinent" vessels penetrate through the pleura and are freely distributed to them. Whenever it so happens that false membranes have been formed on the surface of the pleura, the sub-pleural cellular tissue which corresponds with the locality where that has occurred becomes proportionately thickened and indurated, and it will be necessary, in order to separate the true pleura from the morbid formation by which it is enveloped, to dissect away the false membrane (and it will be found quite possible to do this). The pleura itself can then be discovered, entirely distinct and independent of the false tissue, and such blood-vessels as still remain within it will prove to be in connexion with the pulmonary, and not with the bronchial system.

Induration of pulmonary tissue.

When it occurs that such false membranes are formed, not only is the subjacent cellular tissue thickened and hypertrophied, but the parenchymetic structure itself also (forming the leaflets or pulmonary tissue), in the immediate locality, is at the same time toughened and made to resemble parchment. This toughened and hypertrophied structure, which occupies the situation which in a state of health belongs to the air-cells, can be injected with considerable minuteness by the "sustinent" artery; but it will be found that the altered structure will only allow a very sparing and insufficient quantity of the fluid sent into the pulmonary vessels to pass into its capillaries, although every other part of the lungs might have been injected by these vessels in the most perfect manner. The process of thickening which the tissue has undergone in connexion with the "sustinent" artery will have obliterated and blocked up the capillaries belonging to the pulmonary vessels to such an extent, that it will be found almost impossible to inject them fully.

Bronchial or sustinent veins.

In the cellular tissue lying immediately beneath the pleura, some veins of considerable size are to be seen whenever the sustinent arteries have been fully injected. These veins are never distended by injection from the pulmonary vessels, however perfectly these latter only may have been injected throughout the lungs; and they never fail to become injected, whenever the sustinent arteries are filled, so as to distend their capillaries. They return the blood collected from the subpleural cellular tissue; and this blood is the residue of that sent to that structure by the sustinent artery, and of none other. (*Vide* Series B, No. 5, fig. *a*, page 64, and fig. *b*, page 65.) These veins make their way towards the posterior mediastinum, and terminate in some of the œsophageal veins, in the intercostal veins, in the azygos veins, and, in short, in any of the systemic veins with which they may come into contact.

These are not the only veins which return the blood brought by the sustinent arteries. Some large sustinent veins are always to be found accompanying the larger bronchial tubes. They may be distinguished from the sustinent artery by being less firmly bound down to the bronchial tube, and by the other characters which distinguish veins from arteries. They are found in the loose cellular tissue which intervenes between the large pulmonary veins and the bronchial tubes. They have *valves* and short trunks of anastomosis crossing directly from one sustinent vein to another. In this respect they differ (notwithstanding what has been asserted by Rossignol to the contrary) from the pulmonary veins, which never have any such trunks of anastomosis.

Two contiguous pulmonary veins are universally observed to derive their smaller branches from the same lobules, and these smaller veins intersect each other as they cross the interlobular spaces, so that it is found impossible to separate the lobules and groups of lobules from each other without tearing across some of these small branches; but no direct trunk of anastomosis, such as is seen in the veins of the extremities and in the larger sustinent veins, is ever to be found uniting the trunks of the pulmonary veins.

These particulars respecting the sustinent veins which accompany the bronchial tubes ought not, properly speaking, to have been discussed in this place, while describing those structures which belong to the subpleural cellular tissue and to the exterior of the lungs: they are incidentally mentioned, however, in consequence of the other veins with which they are allied having introduced their notice. The existence of any such veins has been denied by some modern writers; but they cannot easily be overlooked if they be carefully sought for, particularly after the sustinent artery has been injected.

The sustinent veins cannot be injected in a retrograde course, because of their valves; but if proper care be observed, the injection sent into the sustinent artery can be made to flow into them through the sustinent capillaries.

Lymphatics.

Besides the veins already mentioned as occupying the subpleural cellular tissue, a very extensive plexus of lymphatic tubes is found minutely ramifying in the same structure. These lymphatics make their way from the interior of the lungs by passing through the fissures which divide the lobules and the minute leaflets of which the lobules are made up. They are spread out in an intricate meshwork, and form larger vessels, which run in a straight direction across the subpleural tissue to reach the posterior mediastinum.

Nerves.

In the subpleural tissue, also, the terminations of the nerves derived from the pulmonary plexus are to be found. The nerves from this plexus are distributed to every part of the lungs, and in their ramifications correspond very closely with those of the sustinent arteries. It seems pretty evident that the nerves supplied to the lungs have for their office the regulation of the *systemic* function of those organs, and are only connected with the process of respiration in as far as they regulate the contractility and such sensibility as belong to those organs; and thus they in no degree influence the power of the blood to combine with oxygen, nor engender the vital properties which result from that combination.

It would be merely a weak deference to a superstitious tradition to attribute to these nerves the office of manufacturing and supplying these organs with their *vital* susceptibilities and attributes. If the nerves of the pulmonary plexus were, indeed, provided for the purpose of furnishing vital efficiency to the lungs, so as to enable them to execute their task, it would be requisite that those nerves should be at least as extensive as those of the remainder of the body, since it is obvious that the vital changes which are wrought in the lungs are precisely equal, in extent, to the correlative operations which take place in the remainder of the body, considered in the aggregate. Moreover, if those nerves did, in truth, manufacture that vital force, it is clear that some materials would have to be furnished to those nerves out of which it could make that commodity. *Ex nihilo nihil fit.* There are no such materials supplied to the pulmonary plexus.

It is quite reasonable to admit, that just so much contractile power as it is necessary that the various parts of the lungs should enjoy, that just so much sensation as it is necessary that they should be endowed with, may be regulated and brought into harmony with similar states of other portions of the body, associated with them in the mechanical part of the function of breathing, and that these co-ordinating effects may be brought about through the instrumentality of the pulmonary plexus; but it is obviously impossible that that plexus should manufacture or contribute any fresh product of any sort or kind, much less that it should supply the governing stimulus of vital arterialization adequate to the demands of the whole body. There is a natural tendency of the mind to associate the operations peculiar and essential to life with certain ghostly properties, whose leading characteristic seems to be that of delighting to wander among concealed labyrinths and intricate passages; and it is, perhaps, due to this appetite for the mysterious, that the functions and properties of the nerves are almost always looked upon as something supernatural. Equally untenable is the doctrine which would attribute to the brain the faculty of concentrating within itself a reserve supply of the esoteric influences above alluded to, in order to enable the nerves to distribute them, from time to time, to the different parts of the body, in proportion as these may be called upon to exercise their vital functions or attributes. In a modern treatise on Physiological Anatomy, which, unfortunately for science, enjoys great popularity, it is assumed that the vital force or power, whose duty it is to regulate all the natural functions of the animal body, is in some way compressed or concentrated in the brain, and the name of the *vis vitæ coacervata* is given (in accordance with John Hunter) to the essence thus supposed to be enclosed in that organ; and the theory is adopted, that the nerves have the power of uncorking (as it were) this reservoir, and of causing the gaseous or electric influences which have been pent up within it to be distributed over the various organs of the body which may stand in need of its life-giving properties.

Assuming for a moment that this theory had some foundation in fact, it follows that either the brain itself must have the power of generating that compressible fluid or vapour, or that it must first be generated elsewhere, and then carried to the brain.

If the first hypothesis be received,—namely, that it is generated in the brain itself,—it will not be disputed that the blood with which the brain is supplied must furnish the materials by which this is done. In that case, the conclusion would be inevitable that the whole vitality of the body was manufactured out of a mere fractional part of the blood, viz. that portion which reaches the brain.

If, on the contrary, the second proposition be adopted as the more reasonable,—viz., that it is generated elsewhere, and afterwards collected in the brain,—still it would be evident that the arteries carrying blood to the brain must be the channels by which that collection is made. But the arteries which take the blood to the brain go to it *direct from the lungs*, and the blood goes through no intermediate organ from which it can undergo any change, or from which it can collect any fresh supplies of vital influence, since it is impossible to suppose that the left side of the heart can communicate any fresh properties to the blood which passes through its cavities.

Therefore, it is incontrovertible that if the blood going to the brain carries with it the *vis vitæ coacervata,* and imparts it to that organ, the source from whence it derives its supplies of that agent or fluid must be no other than the lungs themselves; and it follows equally convincingly that this fluid, vapour, or agent, which the blood thus acquires in the lungs, must be attained in virtue of the combination of the blood with the oxygen of the atmosphere. But, whatever the qualities or properties of the blood may be which the atmospheric changes thus wrought in the lungs may give rise to, the effects are certainly not confined to that portion of the blood which is sent to the brain, but every portion sent to every individual organ of the body must be equally impregnated with the same peculiarities: therefore, if the brain has indeed the exclusive power of availing itself of this *vis vitæ,* and of laying up a reserve stock of the vital power thus impartially distributed, it must be because other organs have no need or consumption for the *vis vitæ* with which the blood by which they are supplied is so abundantly impregnated, and that therefore those organs take no heed of the vital agent which the cytoblasts of the brain alone have the intelligence to appreciate; and that, in consequence of this apathy on the part of the other organs, the vital quality of the blood is inoperative, except as far as concerns that portion which happens to make its transit through the brain. Then, in like manner, if the body in general has no need of the vital influence, and cannot take cognizance of it until it has been concentrated in the brain, the validity thus imparted to it in the brain would be again destroyed when its concentration was neutralized by the same vital influence being dispersed over the body at large. But it may, perhaps, be urged that though the vital power originally derived from the atmospheric changes excited in the blood in the lungs may exercise an efficacious property not only on the brain, but upon the other organs of the body, it does not follow that the brain may not have the power of retaining, and of concentrating within itself, a reserve supply.

But if this point be conceded, it is abundantly clear that any such accumulation must be due either to the other organs neglecting to use the vitality which is passed through them in conjunction with their blood, and thus allowing it to be inoperative, or else to the fact that the brain itself practises a greater economy of the vital influence, since it is quite evident that there is a strict impartiality in the supply; the blood of all being exactly alike. But if the figment of the concentration of the *vis vitæ* in the brain, and the supposition that the functions of other organs are dependent solely on that organ for their supplies of vitality, be given up, it would follow that, like as the brain, and all the other organs, depend on the lungs for their supply of vital force, as well as for their supplies of arterial blood, so also the amount and degree of vital arterialization in the lungs depend upon the activity of the vital functions in the various organs, of which the brain constitutes one.

In proportion as the vital functions in general are active or otherwise, the respiratory changes are vigorous or the reverse. The *vis vitæ* is the joint product of the coincident activity of both the respiratory and the corporeal actions.

The combination of the oxygen with the blood in the lungs is the *primum mobile* and the measure of every vital change which takes place in the *whole* body; and though the brain may exercise a disturbing or regulating influence in proportion as it duly discharges its own functions, or fails to do so, in like manner may every other important organ of the body do the same thing, and exercise an equally potential control, even to the extent of bringing the whole machinery to a stand-still.

In the physiological publications already alluded to, the function of the lungs is invariably treated as if it were nothing more than a means whereby the body might gain a supply of oxygen, and relieve itself of a certain amount of carbonic acid; and in a modern work, by an author of considerable repute, it is plainly stated that the oxygen so supplied *is neither more nor less than a particular kind of food!* From all these statements the inference might fairly be drawn that the lungs merely performed a subordinate part in the function of digestion; and in point of fact it will be found that in almost all (if not in all) modern works on Physiology, the functions discharged by the lungs are treated as if, of all the processes performed in the body, they were the most unimportant; and any one would be entitled to draw the conclusion, if the opinions of those writers were to be adopted, that if at any time a living animal should happen to have too much oxygen in his system, the ready and easy remedy would be to discontinue breathing for a few days. The other doctrines of a cognate origin which are also advocated in the same works—namely, such as that of the special and individual vitality of the cytoblasts, of which the body is said to consist, and that of the independent reproduction of its various parts by means of those hermaphrodite cells through the agency of their nuclei—and such as the still more startling development, lately advocated by an author of influential name, of the same theory, who boldly asserts that "every animal presents itself as the sum of *vital unities,* every one of which manifests all the characteristics of life" (which, if true, would afford an easy means for the indefinite propagation of individuals),—are all of them too fanciful or too obviously incorrect to be met by serious argument.

Surface of the lungs.

When the pleura and sub-pleural cellular tissue (with the veins, lymphatics, and nerves belonging to the latter) have been entirely stripped off from the surface of the lungs, it is found that the texture of the lungs themselves is broken up into lobules by means of fissures which divide the lobules from each other.

Lobules.

These lobules are wholly distinct and separate from one another, as regards the divisions of the bronchial tube and of the pulmonary artery which enters each of them; but, as already observed, the small twigs of pulmonary veins, crossing the space or interval which separates the lobules from each other, bind the different lobules together, so that they cannot be disunited except by tearing asunder those small twigs of veins.

Inter-lobular spaces.

Lobulettes.

Each individual lobule, again, is susceptible of further subdivision. Some of the lesser bodies thus formed have been called "lobulettes;" but the divisions which constitute the lobulettes are quite arbitrary, and may be made in almost any direction, and into as many subdivisions as may be desired, since each lobulette is only a congeries of the ultimate leaflets, which, again, are small bodies, separated partially from each other

Leaflets.

by a fold or sulcus of the fibrous membrane common to the whole tissue by which they are invested.

The parenchymetic structure of the lungs is wholly made up by an aggregation of these leaflets into lobulettes, of the lobulettes again into lobules, of the lobules into groups of lobules, and of the groups of lobules into lobes.

Quadrilateral bodies.

On the surface of the lungs these leaflets are so arranged as to represent a pavement, consisting of tiles of a somewhat quadrilateral figure. (*Vide* Series C, No. 4, fig. *a*, p. 75.) The boundaries of these quadrilateral bodies correspond with the fissures which separate any one leaflet from those which surround it. The external or upper surface of each of these quadrilateral bodies is covered by an exceedingly vascular distribution of the pulmonary artery, by which it is almost entirely occupied, since almost immediately that the pulmonary veins appear on that surface, they dip down into the sulci which divide the leaflets, and commence the formation of the larger pulmonary veins.

Interlobular veins.

These larger pulmonary veins run along the margins of the lobules in the interlobular spaces. These interlobular veins are joined by other similar veins, and by some which collect the arterialized blood from the plexus belonging to the bronchial mucous membrane. (*Vide* Series C, No. 4, fig. *b*, and fig. *c*, p. 76.)

Characteristic shape of the lobules and leaflets.

Before passing from the description of the external features and characteristics of the lungs, it will be well to mention that certain peculiarities prevail with respect to the shape of the lungs taken as a whole, and that the same characteristics may likewise be traced, not only in each lobe into which each lung is divided, but in each group of lobules, in each individual lobule, and in each leaflet or ultimate subdivision of the same.

Surfaces.

In each and all of these different portions of the lungs, the shape which they all present consists of three distinct surfaces, clearly defined by margins more or less acute. They exhibit, first, an upper and somewhat convex surface, on which the capillary blood-vessels, principally in connexion with the pulmonary artery, are seen; next, an inner or flat surface, forming an interlobular surface, and which in the aggregate corresponds with that portion of the lungs which lies in contact with the pericardium; and, thirdly, the under surface, which is rather concave than otherwise, and is that portion which lies upon the other leaflets or lobules, and coincides in the aggregate with that part of the lung which lies upon the diaphragm. A transverse section of a leaflet, therefore, is somewhat triangular in form, and the space included between the surfaces of each leaflet is filled up with a spongy texture, and the name of air-cells is usually given to the interstices within it. (*Vide* Diagram A, No. 5,

Air-cells.

fig. *c*, page 36.) Each group of lobules, each lobule and each leaflet, may, therefore, as far as these particulars go, be looked upon as a diminutive but perfect lung.

The capillaries belonging to the two surfaces last mentioned,—namely, the under and the interlobular surfaces of the leaflets,—are allied rather to the pulmonary veins than to the pulmonary artery, since the colour which they exhibit when the pulmonary artery and pulmonary veins are injected with fluids of different colours will more nearly correspond with that sent into the pulmonary veins than with that sent into the pulmonary artery. It has been already remarked that the reverse of this occurs with respect to the upper surface, since the capillaries in connexion with the pulmonary artery preponderate in that situation.

A strong resemblance to a vegetable leaf is to be traced not only in the lungs themselves taken in the aggregate, but likewise in every ultimate leaflet into which the whole pulmonary structure is subdivided, as well as in every intermediate lobule or group of lobules. The upper convex surface of each part represents the upper or smooth surface of the leaf, and the interlobular and under surfaces correspond with that portion of the leaf on which the venation appears.

The bronchial tubes and pulmonary artery enter the structure of the different parts of the lung through those two latter surfaces only, and they are never seen, even in the smallest fragment of the lung, to penetrate its structure through that part which represents the upper or convex surface.

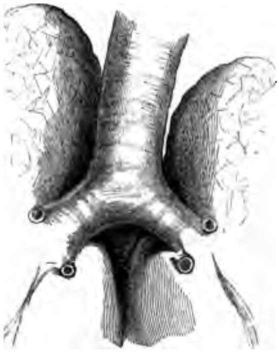
Interior of the lungs.

Passing to the interior of the lungs, the first point to engage attention is the distribution of the bronchial tubes.

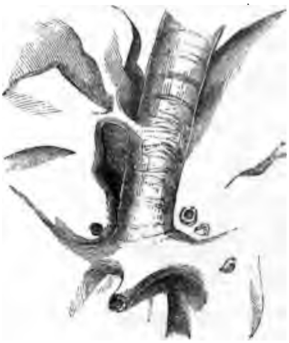
Bronchial tubes.

In ordinary anatomical works, it is common to find it asserted that the bronchial tubes divide successively in pairs: that is to say, that the trachea having what is called "bifurcated," the tubes continue again and again to split into two, in a similar manner. This statement has been almost universally repeated until quite lately, when a recent author has asserted that some of the smaller tubes, instead of dividing in a binary form, merge into a trichotomous kind of arrangement. There is, however, nothing in any part of the lungs which would warrant the statement that there was either a dichotomous or a trichotomous division of the bronchial tube.

Even the so-called bifurcation of the trachea, which is the nearest approach to such an arrangement that is anywhere to be found, is not a true binary division. The left bronchus is much smaller than the right, and is given off as a separate branch from the main stem of the windpipe, but it is not a bifurcation. (*Vide* A, No. 1.) In all quadrupeds, the trachea, previous to reaching the point where it is ordinarily said to bifurcate, gives off a separate and distinct branch, of considerable size, to the upper lobe of the right lung. (*Vide* A, No. 2.) This upper lobe has a sort of peninsula attached to it, so as to cause the right lung to project higher in the neck in those animals than the left does.



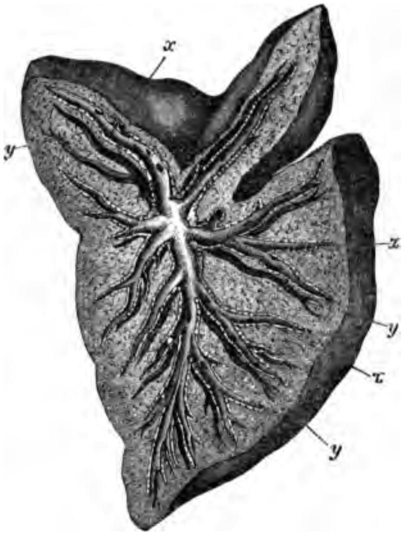
Series A, No. 1, shows the so-called bifurcation in the human lung (much diminished).



Series A, No. 2, shows the division of the trachea in the sheep's lung (much diminished).

If the first division of the trachea be entitled to the name of bifurcation, this bronchial tube, which in the sheep's lung takes its origin nearly two inches above that which ordinarily goes by that name, ought to be considered as forming part of the bifurcation rather than that which is, in point of fact, the second branch given off from the wind-passage.

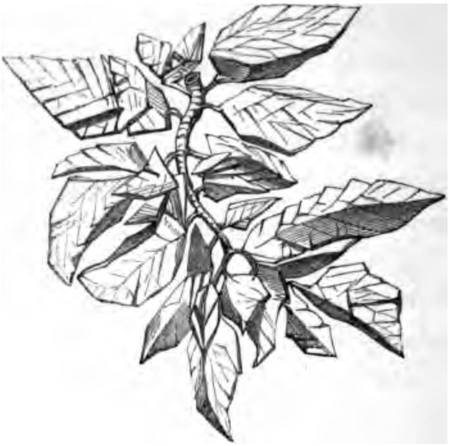
The division of the bronchial tubes, however, instead of being either dichotomous or trichotomous in any part of the lungs, is strictly that of a panicle. In every part a straight diminishing tube may be discovered, which closely re-



Series A, No. 3, shows a horizontal section of the sheep's lung, displaying, *x*, the alternate subdivision of the bronchial tubes ; *y*, the injected pulmonary vein (much diminished).

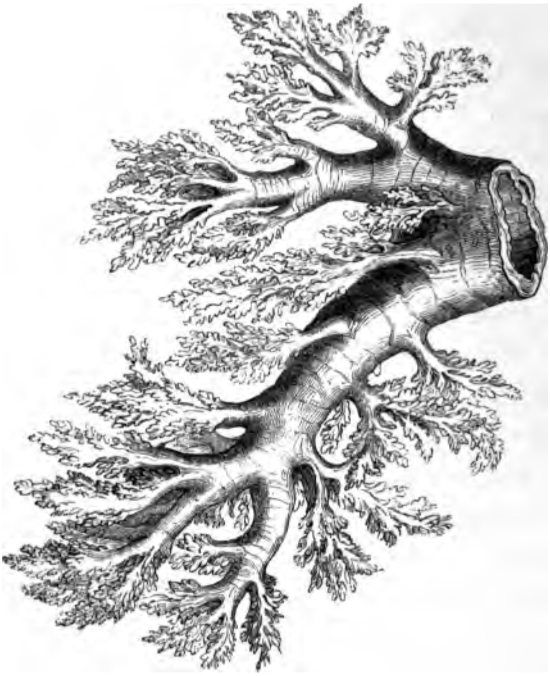
sembles the midrib of a leaf; and from this branches are given off alternately on each side of it throughout its whole length. Each of these secondary branches follows out precisely the same plan of distribution, and this continues to be repeated down to the ultimate terminations of the minutest bronchial tubes. (*Vide* A, No. 3.)

The bronchial tubes thus given off form no sort of anastomosis nor junction among themselves, and they are divided into sets or groups, which remain distinct from each other, and do not become mingled or intermixed. They bear a considerable resemblance to a bunch of grapes, each individual grape being supposed to represent a particular lobule. Each group of lobules, then, is distinct and separate as regards the distribution of its bronchial tubes; and as the peculiarities of the pulmonary artery also strictly coincide in those particulars with those of the bronchial tube (with the course and distribution of which it closely corresponds), and as its branches, like those of the bronchial tube, do not at all inosculate with one another until they finally split up into their capillary subdivisions, it follows that, as regards the pulmonary artery likewise, each group of lobules is quite distinct from those which surround it. The same prevails also with respect to each lobule, and in a modified degree with respect to each individual leaflet. (*Vide* A, No. 4.) Each lobule receives its own special bronchial tube and pulmonary artery, and therefore, as far as these are concerned, might be considered as forming a distinct and independent body, were it not that the sulci which divide the lobules from one another extend only to a limited depth, leaving the bases of the lobules partially in apposition with each other. In the situation where the lobules join, the contiguous leaflets create a kind of anastomosis, and by their instrumentality a communication is established, so that air blown into any particular lobule through its special bronchial tube will readily make its escape by the bronchial tubes belonging to adjacent lobules.



Series A, No. 4, is a diagram taken from the calf's lung, showing that the lobules and groups of lobules arrange themselves into distinct divisions, each with its special bronchial tube (much diminished).

But though each lobule and each group of lobules is in a great measure distinct as regards their appropriate bronchial tubes and pulmonary arteries, the case is strikingly different with respect to the pulmonary veins. These do not, like the former, penetrate, as it were, into the substance of the lobules, and thus become identified with a particular lobule; but they are invariably placed between contiguous lobules, and between contiguous groups of lobules, and collect their venous radicles (conveying, of course, arterial blood) indiscriminately from the lobules between which they are situated. The only pulmonary veins, therefore, which are found in connexion with the minute bronchial tubes and their accompanying arteries are the ramusculi, which collect the blood from the mucous membrane which lines those tubes: the true pulmonary veins, on the contrary, are placed in the interlobular spaces which separate contiguous lobules and contiguous groups of lobules, and as respects the smaller bronchial tubes and their accompanying pulmonary arteries, are placed at a distance from them. The smaller veins issue out from each lobule, and partially cross the interlobular space to join the trunk of the vein. The lobules are thus inextricably sewn together, as it were, by these minute veins, and it is impossible to separate the lobules without tearing asunder multitudes of these interlacing veins. Except for the connexion between the lobules and groups of lobules which these small veins establish, and for the loose connexion which the cellular tissue, with the bronchial vessels belonging to it, afford, and for the kind of inosculation between the leaflets at the base of each lobule, each of these portions of the lung would be entitled to be considered as a distinct and individual organ.



SERIES A, No. 5, fig. *a*, shows a bronchial tube dissected out to its final subdivision (natural size).

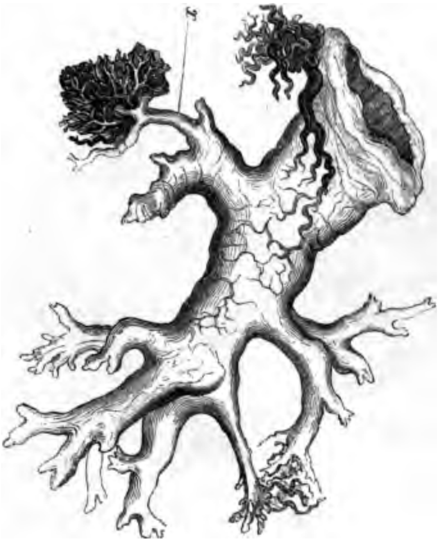
The method in which the lesser bronchial tubes are given off in an alternate manner from the parent tube is seen in Series A, No. 5, fig. *a*.

Numerous erroneous statements have been published respecting the final terminations of the bronchial tubes. In many works it is asserted that the ultimate tissue of the lungs is made up entirely of minute bronchial tubes; so that each air-cell, according to these authorities, is neither more nor less than the termination or blind extremity of a bronchial tube, and consequently, if that were true, it would result that no distinction could be drawn as to what part was pulmonary tissue, and what bronchial tube. Nothing could possibly be more incorrect. A recent author has endeavoured to show that each ultimate bronchial tube terminates in a kind of trefoil, and that an arrangement to which he gives the name of "alveoli" is connected with them. This is entirely a mistake, as nothing of the kind exists.

These errors arise in consequence of the attempt to make out the structure of the lungs by examining specimens which have been inflated and dried. When the lung is thoroughly moist, it can be fully distended by forcing air into the tubes, and the air will have but little tendency to escape from its meshes so long as that moisture is not diminished; but the instant the lung becomes in the slightest degree drier, the air penetrates through the tissue in every direction, and the character of the spaces where the air remains is altered. When, on the other hand, after the pulmonary vessels have been duly injected, the artery with one colour and the veins with another, and when the lungs have afterwards been kept in a moist state, it will be impossible for any one who examines them, either by the naked eye or by the microscope, to fail to observe that the structure of the air-tubes is as distinct and different from that of the true pulmonary or parenchymetic tissue as it is possible for any structures to be.

Whenever the smallest fragment of such an injected lung is examined by the microscope, any person, however uninstructed, would be able at once to discriminate which was bronchial tube, and which pulmonary tissue. But the case is quite different if a portion of dried lung be examined: the pulmonary tissue will then have become shrivelled up and agglutinated together, so that the whole structure will appear as if it consisted of nothing else but minute bronchial tubes, in consequence of its spongy tissue being quite obliterated.

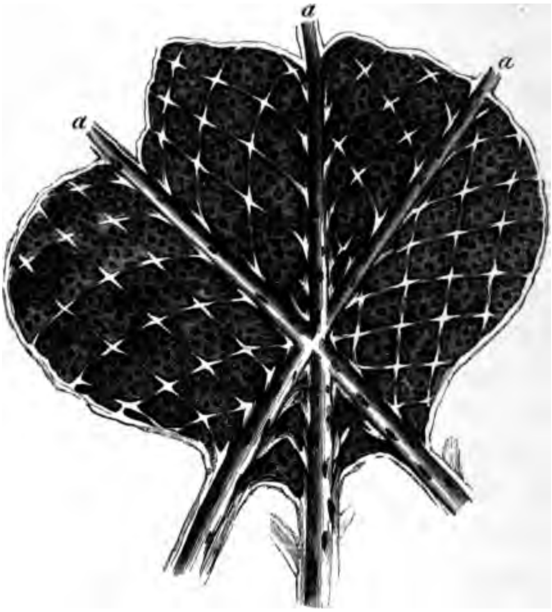
But, avoiding these errors and carefully inspecting moist specimens of properly-injected lungs, it will be found that the terminal bronchial tubes split up into certain minute branches, which, as they differ both from the ultimate pulmonary tissue and from the true bronchial tubes, ought, properly speaking, to be considered as holding an intermediate condition between the two, and, as such, to be entitled to a distinct appellation. It is now proposed to call them, for the sake of distinction, pedicels. (*Vide* A, No. 5, fig. *b*.)



Series A, No. 5, fig. *b*, (sheep's lung,) shows a terminal bronchial tube, with numerous pedicels, one of which, *x*, is attached to a leaflet (magnified 5 diameters).

Pedicels.

The length of each pedicel does not much exceed its diameter, and the pedicels are not furnished with what may strictly be called a mucous membrane. The walls of the bronchial tubes, up to the point of giving off the pedicels, are of considerable thickness, and their interior is lined with mucous membrane; and this is covered with a very remarkable and very vascular plexus, which is exclusively connected with the pulmonary vessels, and more particularly with the pulmonary veins. At the spot where the pedicels are given off, the structure of the bronchial tubes splits, as it were, into two layers; the thicker, firmer, and more elastic of the two expands and encloses an



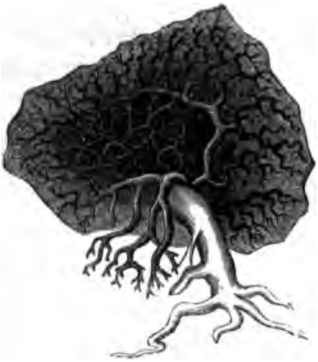
SERIES A, No. 5, fig. *c*, is a diagram representing, on an exceedingly magnified scale, a section of a leaflet. It shows how each leaflet receives several pedicels from different ultimate tubes, and how the interior of each leaflet is divided into greater and lesser air-cells, which freely communicate with one another and with the pedicels. It shows also that the interior of the leaflets is divided into its compartments by the interlacing of *processes* given off from the different pedicels. It further shows that some of the pedicels terminate in little filmy tufts, *a*, *a*, *a*, which appear on the surface of the leaflets, and become continuous with the loose flocculent tissue by which the leaflets are surrounded.

ultimate portion of the lungs (called in this Treatise *a leaflet*), and becomes continuous with the fibrous tissue which encloses the rest of the parenchymetic structure, dipping down between the different lobules and leaflets, so as to form the sulci by which they are divided. Five or six of the pedicels are usually given off at the spot where the bronchial tube undergoes this change, and each of them enters a distinct leaflet; but each of these leaflets receives numerous pedicels, each given off from a separate ultimate bronchial tube. Each pedicel, on entering the leaflet, expands into processes which extend to the perimeters of the leaflet, and divide its interior into numerous compartments. These compartments usually go by the name of "air-cells." They are formed in a manner strongly resembling that by which the hyloid membrane divides the vitreous humour of the eye into *its* "cells." (*Vide* A, No. 5, fig. *c.*)

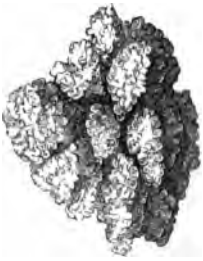
Each leaflet receives distinct filaments, given off from the pulmonary artery, which forms a minutely anastomosing plexus around its walls, and on the processes which constitute its interior cells. (*Vide* A, No. 5, fig. *d.*) Each part of these receives a very complete supply of still more minute vessels derived from the sustinent artery.

The shape of these leaflets has already been described as presenting three distinct surfaces, each defined by a margin more or less acute.

The basement membrane of these leaflets is a continuation or expansion from the fibrous structure of the bronchial tubes, and forms a tough elastic capsule which limits the shape of the lobules and leaflets, and dips down into the sulci between each of them. (*Vide* A, No. 5, fig. *e.*)



Series A, No. 5, fig. *d*, shows a pedicel terminating in a leaflet. The leaflet is covered by a plexus derived from the pulmonary artery (magnified 20 diameters).



Series A, No. 5, fig. *e*, shows a small bundle of leaflets distended with plaster of Paris (magnified 3 diameters).

In consequence of each leaflet receiving several pedicels from as many distinct ultimate bronchial

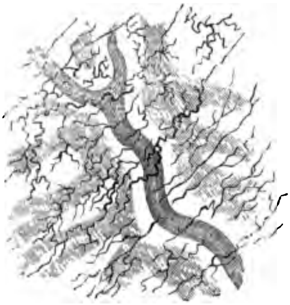
Anastomosis of ultimate bronchial tubes.

tubes, there is a very minute anastomosis established between these tubes, by means of the leaflets which unite the pedicels of various bronchial tubes, which would otherwise have no communication with one another. No other communication nor anastomosis, except this, exists between any two bronchial tubes in any part of the lungs, (of course the place where each tube branches out from the larger one, from which it takes its origin, is not included in this statement,) and the only communication between the air contained in adjoining lobules is that which the leaflets at the base of each establish by means of their pedicels. It is in consequence of these adjoining leaflets thus blending together at the base of each lobule, that it is found impracticable entirely to separate any particular lobule from those which are adjacent to it without inflicting some injury to the structure of both, although the sulci which divide them may be marked and very decisive. The same observation applies to the leaflets, since they also cling in like manner to the other leaflets which adjoin them: it applies also to the lobes themselves, which cannot be wholly separated from the other lobes without sustaining some damage to the tissue at the base of each, where they are adherent.

It will not be necessary to add anything to what is ordinarily mentioned in anatomical works

Cartilaginous rings and bands.

respecting the cartilaginous rings and bands by which the larger bronchial tubes are partially surrounded, nor respecting the fibrous membrane which connects these rings and bands, and constitutes the framework of the tubes themselves where the cartilaginous rings are absent; it is sufficient to say that the whole of the fibrous and fibro-cartilaginous portion is furnished with blood from the sustinent artery, and not in any degree from the pulmonary vessels. (*Vide* A, No. 5, fig. *f*.) It is different with respect to the mucous membrane by which these tubes are lined: this receives a moderate quantity of extremely minute capillary blood-vessels, derived from the vessels above mentioned, evidently merely for the repair of its tissue, in common with every other part of the lungs, which, in like manner, is supplied from the same source, for the same purpose; but the



Series A, No. 5, fig. *f*, shows the interior of a bronchial tube, with the fibro-cartilaginous portion minutely injected from the so-called bronchial arteries. The mucous membrane has been carefully removed. (Magnified 20 diameters.)

special vascular plexus with which the surface of the mucous membrane is covered is wholly in connexion with the pulmonary vessels, and more especially with the pulmonary veins, and is not in the slightest degree associated with the sustinent arteries.

Before entering more minutely into the subject of the distribution of the blood-vessels in the bronchial tubes, in the mucous membrane, in the leaflets, and in the structure of the lungs in general, as well as into the method to be adopted in injecting and preparing the lungs so as to demonstrate the ramifications of the blood-vessels in each particular part, it now only remains to speak of the rugæ with which the mucous membrane is corrugated, in order to complete that branch of the subject which relates to the general structure of the lungs.

Rugæ.

The rugæ are obviously caused by the contractile property of some circular fibres which embrace and surround the longitudinal ones.

Longitudinal and circular fibres.

The rugæ are only visible when the diameters of the bronchial tubes have been diminished by the contraction of the circular fibres. When the whole lung has been kept distended for some days by pumping salt-and-water or some viscid liquid into the bronchial tubes, the tendency of those tubes to contract will be overcome, and the mucous surface will then present a smooth appearance, free from any rugæ.

Fibrous capsules.

The contractile fibres, both longitudinal and circular, are continuous with the fibrous tissue, which has been already described as an expansion of the outer coat of the bronchial tubes, and which furnishes a kind of capsule or framework to the leaflets and lobules.

The contractile action of the circular and longitudinal fibres of the bronchial tube, and of the capsules of the leaflets and lobules, is doubtless controlled by the operation of ONE cause, which influences them all, and compels them to act in unison with one another; and not only so, but likewise causes them to act in combination with the complicated machinery of muscles, external to the lungs, which are occupied in the process of mechanical breathing: and it is as clear as any physiological deduction can possibly be, that the nerves of the pulmonary plexus, and more particularly that part which belongs to the vagus nerve, are the agents by which the unanimity of the muscular actions necessary to accomplish the function of alternately expanding and contracting the chest, with the allied phenomena (*e.g.*, coughing and sneezing), is brought about.

It is, however, of great importance that a clear distinction should be drawn between the action by which the chest is mechanically filled with air by its alternate expansion and contraction, and that physiological process and its immediate results, which depend upon the amount and degree with which the oxygen combines with the blood in the lungs, after the atmosphere has been brought into contact with it, through the muscular influences provided for that purpose. The action of a fly-wheel in a watch may be essential, in order to set free at proper intervals the motive force of the mainspring of the instrument; but it is not the fly-wheel which puts the whole chain of events into operation, nor, indeed, which sustains the movements of the fly-wheel itself.

Objects to be obtained.

In making an injection of the lungs, the only result that can be at all worth aiming at must be to be enabled thereby to discriminate one set of blood-vessels from another, and to make out the distributions and peculiarities of each. If, however, the object be merely to make ornamental preparations, without doubt that end may be attained with very considerable success, and an exceedingly small amount of trouble, by using injection of only one colour, and by adopting the convenient theory, that they all, arteries and veins, anastomose together, supply the same tissues, and are in every respect alike.

Size and vermilion.

If this plan be adopted, and this end only sought after, an injection consisting of size and vermilion will answer all the purposes very admirably: beautifully-injected specimens can be made for the microscope by these means, but no physiological deductions can be drawn from them.

The vermilion will withstand a great deal of washing and coarse manipulation, which would destroy any preparations containing injections made with distinctive colours.

Difficulties to be overcome.

There is also no difficulty in making any number of the minutest injections of a more useful character, when a suitable apparatus for the purpose is used, which will demonstrate the course and peculiarities of each particular set of blood-vessels, and in which each set of blood-vessels may be kept distinct, so as to be readily recognised, by causing them each to be filled with a different-coloured fluid. But the real difficulty consists in afterwards preserving the preparations made in this manner, and in making microscopical objects from them which would, at a future time, exhibit the anatomical facts in a clear and decisive manner. The size which is used in these injections continues for a considerable time to exude from the vessels, and to infiltrate the tissue, causing at first a cloudiness, and afterwards an opacity, which prevents the minute capillaries from being distinguished. This opacity remains sometimes for months, but it becomes at length re-dissolved: frequently, however, the preparations are destroyed by efforts made with a view to hasten this process of clearing. These difficulties are not met with, at least to any considerable extent, when all the vessels are injected with vermilion, because this is a material which is not liable to lose its colour, when solvent fluids are used to clear away the superfluous size.

Apparatus necessary.

The apparatus by which the specimens were made from which the facts produced in this treatise were elicited, consisted of two pumps of equal dimensions, each fitted with a solid brass plunger ground to fit its barrel. They were made to fix firmly to the table; and each was supplied with an appropriate suction and delivery pipe, and furnished with suitable valves. The piston of each was made to lift by means of a lever-handle with a parallel motion, so as to cause the pressure to be perpendicular; and both handles were so bent that they could be lifted by one hand at the same moment.

By raising the handles, each barrel was filled with a fluid of a particular colour; and by letting the handles descend by their own weight, or with such additional weight as it was thought proper to attach to either of the levers, or to both, the fluids were driven onwards, each independently of the other, with a *vis a tergo* not exceeding the weight of the pistons with their handles. The pressure, therefore, which was made on the coats of the vessels into which the fluid of either was propelled, was governed by the resistance which these gave to the onward flow of the liquid, but could never exceed the pressure per square inch which the adjusted weight of the pistons exercised upon the fluid in the barrel of the pump.

By simply raising both handles at the same moment, the pumps were filled with their respective fluids; and by allowing them to descend passively, all jerks and violence were avoided, and the respective liquids were allowed to flow into their appropriate blood-vessels through flexible tubes which connected the pumps with them. The fluids themselves, into which the suction-pipes were inserted, were kept of a proper temperature by being immersed in a water-bath.

Precautions to be used.

The operation of injecting the blood-vessels was by this means made a very gradual one, and could be spread over a considerable time without fatigue or provoking sudden muscular efforts on the part of the operator. Occasionally the handles were supported, so as to allow the capillary blood-vessels to contract, and, by their own elasticity, to propel onwards the fluid already injected into them, and afterwards to afford them an opportunity of being again distended with the fluid: an action somewhat resembling the ordinary pulsations of the arteries was thus communicated to the blood-vessels.

By adopting this plan, the uncertainties and irregularities attendant upon all injections made by muscular effort were got rid of.

General Observations as to the Plan to be adopted in making Injections either of the Pulmonary or of the Sustinent Vessels.—In order to make an injection of the pulmonary blood-vessels, so as afterwards to be enabled to distinguish which is pulmonary *artery*, and which pulmonary *vein*, it is not only requisite that the arteries should be injected of one colour and the veins of another, but it is likewise of importance that they should both be done at the same time, so that the two kinds of injection should meet in the capillaries: otherwise it will be found that the injection which is first made, whether it be into arteries or veins, will flow on through the capillaries, and distend vessels appropriate to the opposite colour. It is also desirable (except merely for the purpose of proving that it can be done) not to attempt to inject both the pulmonary and the sustinent vessels in the same specimen. It is always preferable to inject the sustinent vessels exclusively in one preparation, and the pulmonary vessels in another.

When this is done, it will be observed that particular vessels, which are never injected from the pulmonary system, are well distended by injecting the sustinent arteries; and that a perfectly distinct set of vessels, belonging exclusively to the aortic system, and having very marked peculiarities of their own, are brought to light by such an injection: and it is further seen that such an injection will never in any case, except as the result of rupture, enter those vessels which are peculiar to the pulmonary system.

When, on the other hand, the pulmonary

vessels are alone injected, it always results that the injection is confined to a particular distribution, which is perfectly definite, and never encroaches upon that peculiar arrangement which is allotted to the sustinent arteries. If, however, it be attempted to inject the sustinent arteries with one colour and the pulmonary vessels with another in the same specimen, it will be found that the pulmonary vessels so greatly preponderate in dimensions and number over the sustinent, that the latter can afterwards scarcely be distinguished, in consequence of their becoming completely buried and concealed, as it were, by the pulmonary injection, and by the size which exudes from it. Even in the cases where the sustinent vessels alone are injected, so as to give a uniform yellow colour to the whole lung, it is requisite that the greatest care should be observed to avoid their becoming quite obscured and indistinct from the exudation of superfluous size which is apt pertinaciously to cling to the tissue, and which it is generally found very difficult to detach from it.

To inject the pulmonary vessels separately, it is convenient to adopt the following plan:—

To inject the pulmonary system.

Having opened the pericardium, one injecting-pipe, provided with a stopcock, should be inserted through the walls of the right ventricle into the pulmonary artery, and be carefully secured there by a ligature passed around the root of the pulmonary artery.

Another injecting-pipe, also furnished with a stopcock, should then be inserted into the left auricle through its auricular appendix, and secured in its place by a ligature passed around the appendix, which requires to be drawn forward by an assistant. In order to guard against the risk of injecting the sustinent artery and its capillaries by the same fluid which is being forced into the pulmonary veins, it will be desirable that a strong ligature should be passed around the root of the aorta, so as to prevent any of the injection which might be forced through the mitral valve into the left ventricle from finding its way into the aorta.

These preliminaries having been arranged, it is advantageous, in the next place, to pump a quantity of warm water through the pipe inserted into the pulmonary artery, and to continue to do so until it passes out quite clear through the pipe inserted into the left auricular appendix. The object of this is to wash away the blood, which would otherwise remain in the capillaries of the pulmonary vessels, and would prevent the coloured fluid from duly entering them. This done, the suction-pipe of each pump is to be placed in the vessel containing its appropriate injection. If the intention is rather to show the capillaries in connexion with the pulmonary artery in preference to those more immediately in relation with the pulmonary vein, it will be desirable to use freshly-precipitated chromate of lead in liquid size for the pump which is connected with the pulmonary artery, and the ordinary injection of size and vermilion for that allotted to the pulmonary veins; and in this case an additional weight should be attached to the lever belonging to the pump which propels the liquid into the artery. If, on the contrary, it be required to demonstrate the tufts of capillaries from which the pulmonary veins take their origin, then it will be necessary to use the yellow injection for these vessels, and the red for the arteries, and to apply the preponderating force on the pump which propels the yellow. The reason of this is, that the yellow injection readily penetrates capillaries which the red injection can only with difficulty be made to enter, and after the injection has been made the yellow vessels show themselves more vividly in contrast with the red.

From this it will be seen that it depends upon the circumstance as to which of the two has been subjected to the preponderating pressure, to determine whether the injected capillaries rather partake of the colour which is sent into the arteries, or of that sent into the veins.

Having made these preliminary arrangements, the handles of both the pumps should be raised at the same time; and then they should be allowed to descend passively, and great caution should be used (particularly at first) that the injection is not too suddenly or rapidly made, and that the force is not prolonged; but that the blood-vessels should have opportunities afforded them of relieving themselves from their distension, by causing the handles of the pumps from time to time to be supported, so that the pressure, being temporarily removed, the capillaries and larger vessels may contract by their own elasticity, and their coats may thus escape being stretched to a degree that might otherwise cause them to burst.

In order to succeed thoroughly in making the injections, two important particulars are to be kept in view: first, to allow the operation to occupy a very considerable duration of time, applying the pressure very gradually, and carefully avoiding all jerks or violence; and secondly, to persevere in the injection for a long time, at intervals, even after the lung to the naked eye appears to have received its full supply of injection. The size will continue to stream out by filtration, through the tissue of the lungs, leaving the solid part of the injection in the blood-vessels; and the perfection of the preparation will afterwards be in proportion as the solid part of the injection is made to occupy the interior of the blood-vessels, to the exclusion of the size.

Having concluded the injection, the whole should be suspended for at least a week before it is cut, in order to allow the size which continues to exude from it to drain away as much as possible; it should then be washed thoroughly, and afterwards allowed to soak in weak spirit and water, to which some pure naphtha should be added.

To inject the sustinent vessels.

Having injected thus one pair of lungs, in which the course and distribution of the pulmonary vessels can afterwards be studied, and from which preparations for the microscope illustrative of every part can be made, another pair of lungs should be injected, specially to demonstrate the course and distribution of the (so-called) bronchial vessels; and in order to carry out this result the following steps should be taken:—

The whole of the contents of the chest, including the aorta, should be removed from the body, taking care to have a sufficient length of each of the intercostal arteries still attached to the trunk of the aorta, so that they may each be secured by ligature.

A ligature should be applied around both extremities of the œsophagus, and on both venæ cavæ, on both ends of the vena azygos, and, in short, on the cut ends of all the veins. One injecting-pipe, with a stopcock, should be inserted into the arteria innominata through its cut end, and securely fastened there; another similar pipe, with a stopcock, should be fastened in the extremity of the thoracic aorta. The object of this latter is, that when the injection is pumped into the aorta through the arteria innominata, the air contained in the aorta, in the first instance, may make its escape through that stopcock; and when the injection is in progress, that the stopcock in the extremity of the aorta may be occasionally opened, so as to allow the injection sent into the aorta to be renewed from time to time with fresh and warm fluid; since it happens that, as the injection sent into that vessel is only slowly disposed of by the sustinent and coronary arteries (which latter are purposely injected at the same time, in order to give additional scope and elasticity, and to avoid the risk of the pressure becoming too great, by being exclusively directed on to the sustinent arteries), there would be considerable danger of causing the trunks of those arteries to burst before their capillaries were filled, unless these precautions were taken. Ligatures must also be put on the left carotid and subclavian arteries, and the cut edges of the pleura and cellular tissue of the posterior mediastinum should be gathered into bundles and enclosed by ligatures. Ligatures should also be applied on the four pulmonary veins externally to the pericardium: great care must, however, be observed not to include the sustinent artery within these ligatures. The object of these ligatures last mentioned is to prevent any injection which might be forced through the mitral valve into the left auricle from passing into the lungs through these veins, and thus causing the vessels belonging to the pulmonary system to become injected.

It is necessary that freshly-precipitated chromate of lead should be used for the purpose of injecting the sustinent arteries, because the capillaries belonging to these vessels are so exceedingly minute that they will not allow an injection consisting of vermilion to enter them, however finely this may have been levigated.

It may occasionally happen, when an injection is made through the sustinent arteries, that, in consequence of some violence being used, the capillaries in connexion with the arteries are made to burst into one or more of the vessels belonging to the pulmonary system, and then the pulmonary vessels of one or more of the lobules, and even of a group of lobules, may become injected from the sustinent arteries: but whenever that happens, it is always in consequence of a clumsy amount of force having been employed. When this accident takes place, it will usually prove that it is one of the pulmonary arteries, and not one of the pulmonary veins, which sustains the damage through the rupture of its vasa vasorum (which are exclusively furnished from the sustinent arteries), and that though some of the pulmonary capillaries supplying the parenchymetic structure may become injected in consequence, the peculiar plexus which is dispersed over the mucous membrane of the bronchial tubes, and which is more closely connected with the pulmonary veins, will be the very part which will escape being injected; whereas, on the contrary, if this plexus were, as is commonly asserted, supplied by the sustinent arteries, it ought invariably to be injected whenever the sustinent arteries are themselves filled: but it has been shown *that it is impossible to inject this plexus* from that source, even in those cases where by accident a part of the pulmonary capillaries may receive the injection sent into the bronchial arteries.

In giving directions that the injection-pipe should be inserted into the arteria innominata rather than into the commencement of the aorta, several advantages are sought: the necessity for opening the pericardium and wounding the tissue of the heart is avoided, additional scope is given to the injection by allowing a part to flow into the coronary arteries, and the risk of applying a ligature, so as to obstruct the passage of the fluid into the principal sustinent artery, is escaped. No other vessels but those in connexion with the aorta can possibly receive any direct supply from this method of injection.

Were there any anastomosis between the sustinent and pulmonary vessels, it must invariably happen that these latter would become injected whenever the sustinent arteries were filled: but, on the contrary, such an event NEVER occurs, and can *never be made* to occur, except in an isolated portion of the parenchymetic structure, as the direct result of violence by the bursting of its vasa vasorum; and never under any circumstances *has it ever yet happened to any individual* that the plexus peculiar to the bronchial mucous membrane has been injected from the sustinent or so-called bronchial arteries.

The injection from the sustinent arteries, when properly made, is always seen to extend into the veins on the surface of the lungs; and this result could not take place without the pulmonary vessels becoming at the same time filled, had there been any anastomosis between them and the bronchial blood-vessels. But the injection from the sustinent arteries invariably does pass into those veins on the surface of the lungs; and it can be shown to do so in a hundred consecutive injections, without in any one instance the pulmonary capillaries or vessels becoming in the slightest degree injected.

Moreover, it will be found that the injection also enters those larger sustinent veins which accompany the bronchial tube, and flows through them into the right auricle,—but in no case penetrates into the left auricle, which it would certainly do were there any communication between the sustinent and the pulmonary vessels.

Examination of the injected lungs.

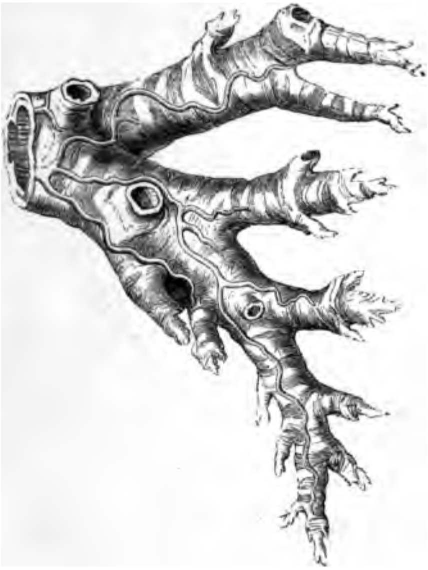
Two pairs of lungs, then, having been injected in the manner just described, it remains to notice the appearances which each presents when they are afterwards examined.

To begin with that in which the sustinent arteries have been filled with yellow injection.

The veins found in the subpleural surface have been already mentioned; and as much has likewise been said respecting those which accompany the larger bronchial tubes as it is requisite to expatiate upon.

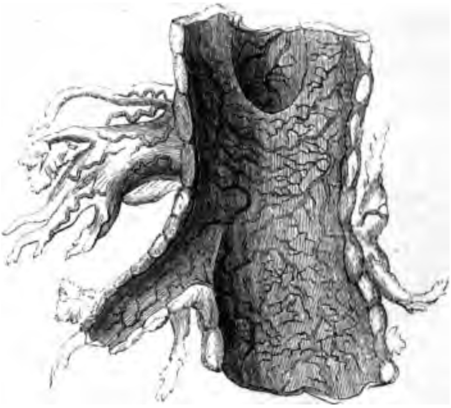
Distribution of the sustinent or so-called bronchial arteries.

The sustinent arteries accompany closely the bronchial tubes in all their ramifications, being firmly bound down to them. (*Vide* B, No. 1.) They divide as the tubes themselves divide, but



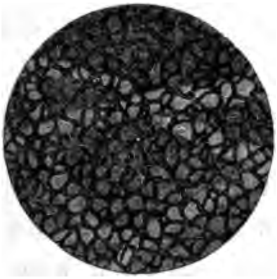
SERIES B, No. 1, (sheep's lung,) shows the ramification of the trunks of the sustinent arteries on the external surface of the bronchial tubes (natural size).

become more numerous, and give off branches which ramify in the different layers of the sub-pleural cellular tissue. The sustinent arteries also supply freely the fibro-cartilaginous structure of the bronchial tubes, and the fibrous structure also where the cartilages are absent, with a free ramification of fine vessels, and some of these extend in the form of exceedingly minute capillaries into the tissue of the mucous membrane which lines them. (*Vide* B, No. 2.) These are exceedingly minute, and they occupy a distinct and independent course, making no anastomosis with the proper vascular plexus which is spread over the mucous membrane.



SERIES B, No. 2, (sheep's lung,) shows the interior of the bronchial tube. The larger sustinent vessels are visible through the transparent mucous membrane: some exceedingly minute capillaries spread into the mucous membrane (magnified 2 diameters).

The mucous membrane requires a supply of vessels for the repairs of its tissue, in common with that of the remainder of the lungs; and these small capillaries derived from the sustinent artery are evidently adapted for that object; while the much more vascular plexus connected with the pulmonary vessels is wholly and exclusively devoted to a *respiratory* purpose, in which the secretion of bronchial mucus is included, and the two sets of vessels are as distinct in their ramifications as they are in their functions. This point has been established beyond any possibility of dispute, by preparations being produced in which both sets of vessels are to be seen clearly and unequivocally injected with materials of different colours in the same specimen, and in which the ramifications of both are displayed most evidently, each totally unlike, independent of and distinct from the other. (*Vide* B, No. 3.)

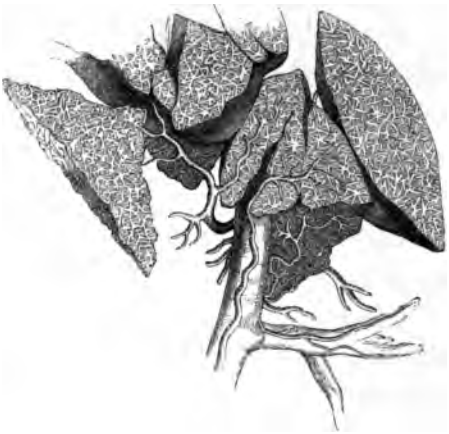


SERIES B, No. 3, (sheep's lung,) shows a portion of the mucous membrane minutely injected by large capillaries belonging to the pulmonary vessels, as presented by the dark lines, and by some excessively minute capillaries: these are shown by the white lines (magnified 20 diameters).

A careful injection of the sustinent vessels was first made, and the pulmonary vessels were injected with fluid of a different colour on the following day. Had there been any anastomosis between the two kinds of vessels, it is clear that the pulmonary capillaries, being much the largest, would have been filled with the first injection, and could not afterwards have been injected with fluid of a different colour. While, therefore, the mucous membrane receives a moderate quantity of excessively minute capillary vessels, derived from the sustinent artery, for the purposes of that which has been called (though erroneously) its *nutritious* supply, it is at the same time furnished with a prodigiously vascular and abundant plexus of vessels, derived from the pulmonary system, in order that the facilities for exposure to air which the large surface of bronchial membrane affords may be available for the function of respiration.

But, as the fibro-cartilaginous structure of the tubes, and the fibrous tissue where the cartilages are absent, do not possess any surface to which the air can gain access, it is found that they do not receive any distribution whatever from the pulmonary vessels, but are freely supplied, as far as their own requirements are concerned, with capillaries exclusively belonging to the bronchial system. Certain minute vessels, it is true, of the pulmonary system connected with the air-cells, or more properly with the leaflets, which immediately surround the bronchial tubes, penetrate *through* the fibro-cartilaginous and fibrous structure of the tubes in order to reach the plexus lining the mucous membrane; and certain other vessels, also, which collect the blood from that plexus, pierce in the other direction the fibrous structure to join the ramusculi which are dispersed over the external surface of the tubes, and collect the arterialized blood from the plexus within it. Both of these are in connexion with the pulmonary vessels; but although they pass directly through the fibrous and fibro-cartilaginous tissue, they are never, under any circumstances, distributed to them. (*Vide* p. 72.) It is invariably the case that these tissues derive their supply wholly and exclusively from the sustinent vessels; and whenever the pulmonary vessels are the only ones injected, it will always be found that these structures are not in the least injected, however minutely every portion of the pulmonary system may have been filled.

Having supplied branches to the tissue of the bronchial tubes, and to the layers of the cellular tissue which spread out from the places where the bronchial tubes are given off, the diminished trunks of the sustinent arteries continue to accompany the tubes until they enter the pulmonary tissue, and are there dispersed in an exceedingly fine plexus distributed equally and minutely over every part, and supply freely all the processes of fibrous tissue by which the interior of each leaflet is subdivided into its compartments. (*Vide* B, No. 4, fig. *a* and fig. *b*.)

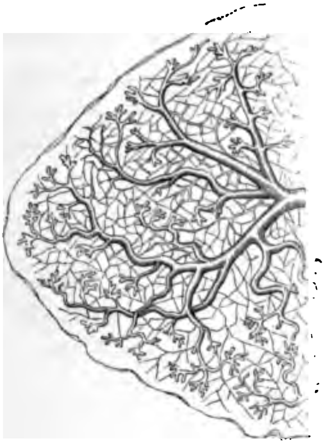


Series B, No. 4, fig. *a*, shows the distribution of the sustinent capillaries in the leaflets (magnified 3 diameters).

Series B, No. 4, fig. *b*. A portion of the same as fig. *a* (magnified 20 diameters).

Emerging from these, the commencement of the sustinent *veins* can be distinguished, which afterwards run a straight course peculiar to themselves, in contact with the pedicel.

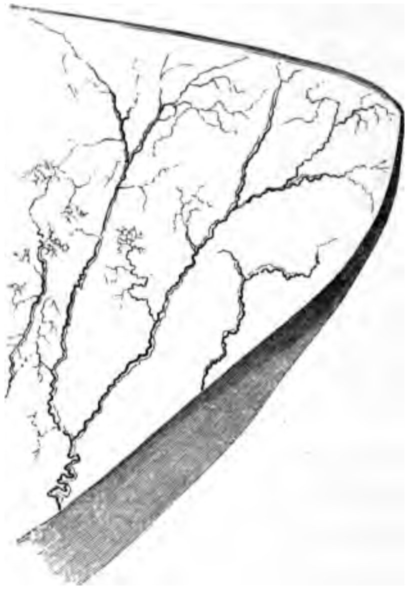
The plexus in the leaflets is much the most vascular of any distribution of the sustinent artery: it is perfectly independent of the pulmonary vessels, and is evidently provided for the reparation of the tissue of the leaflets and air-cells; which office it is equally evident the pulmonary vessels are not in the least concerned in, since their ramifications are simply such as will most perfectly ensure their thorough exposure to the air.



SERIES B, No. 4, fig. *c*, shows the commencement of the sustinent veins, injected from the sustinent arteries, through exceedingly minute capillaries (magnified 20 diameters).

Ramification of the terminal sustinent arteries in the subpleural cellular tissue.

In addition to the branches of the sustinent artery already enumerated, some minute terminal twigs accompany those small bronchial tubes which have already been described as reaching the surface of the lungs, or of the lobules, without terminating in leaflets: guided by these tubes, these small arteries reach the surface of the lungs, or of the lobules, and there form an intimate anastomosis with other branches of the same artery in the subpleural cellular tissue, and in the interlobular spaces. (*Vide* B, No. 5, fig. *a* and fig. *b*.)



SERIES B, No. 5, fig. *a*, shows the apex of one of the lungs, with the sub-pleural sustinent veins, injected through the sustinent arteries (natural size).

The veins by which the blood is collected from the sustinent arteries have been already described.

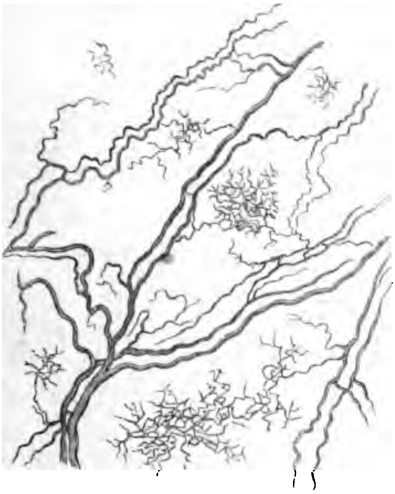
Distribution of the pulmonary vessels.

To proceed, in the next place, with the consideration of the distribution of the pulmonary vessels.

It will be found that nothing can be easier than to trace out the course and ramifications of the pulmonary artery and veins, when a pair of lungs injected in the manner above described, with the arteries of one colour and the veins of another, is examined. The mode of distribution of each is marked, decisive, and invariable.

Pulmonary artery. The pulmonary artery is always seen accompanying the bronchial tube, dividing as it divides, and maintaining an exact correspondence with its subdivisions down to the point at which the terminal bronchial tubes give off their pedicels.

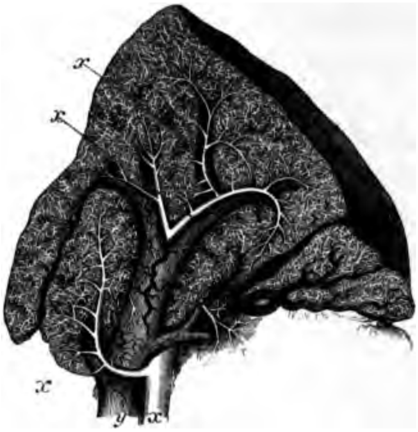
In some works it is asserted that, as they diminish in size, the pulmonary arteries become more numerous than the bronchial tubes. This



Series B, No. 5, fig. *b*. A portion of the foregoing engraving, p. 64 (magnified 20 diameters).

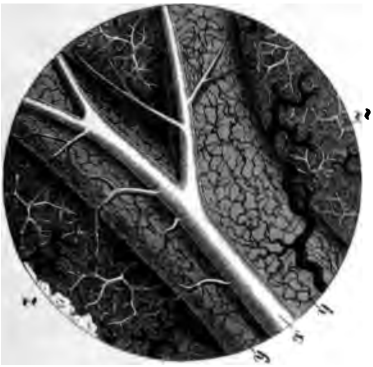
is not the case. Wherever there is a bronchial tube, there is also one corresponding pulmonary artery, and never more than one.

Throughout the lung, the pulmonary artery always runs on the upper side of the bronchial tube; and whenever the bronchial tube is of sufficient size to have an accompanying pulmonary vein, this is placed as universally underneath the bronchial tube. The smaller bronchial tubes and pulmonary arteries are not accompanied by a corresponding pulmonary vein, as this is placed at a distance, being found in the interlobular fissure which separates the lobules; but as the pulmonary veins increase in size, they approach



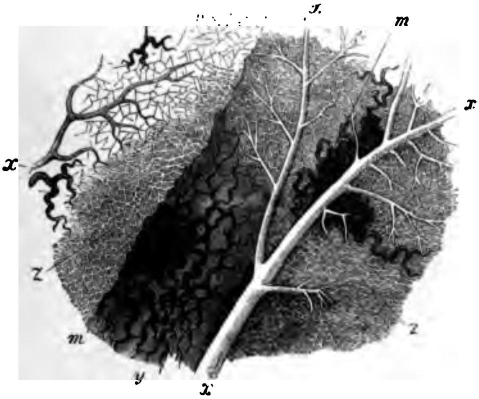
Series C, No. 1, fig. *a*, (sheep's lung), shows the pulmonary artery x accompanying the bronchial tube, and subdividing as it divides down to its capillary distribution (magnified 2 diameters).

one of the larger bronchial tubes, and then run in apposition with its under surface.



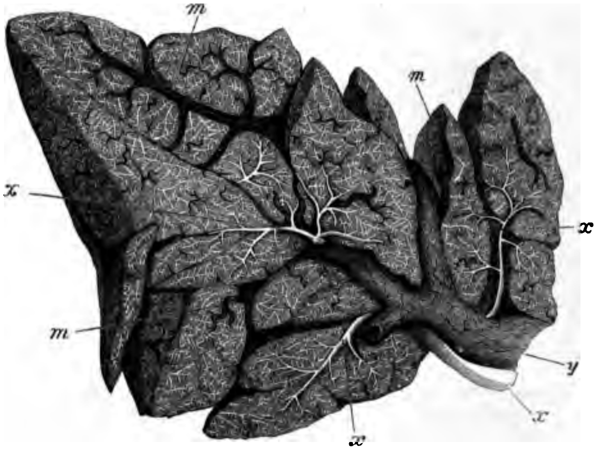
Series C, No. 1, fig. *b*. A portion of the same as fig. *a* (magnified 20 diameters).

In following out the course above described,



Series C, No. 2, fig. *a*, (sheep's lung,) shows the ultimate distribution of the pulmonary artery in capillaries which freely anastomose among themselves, and are exclusively distributed to the leaflets. *x*, Pulmonary artery terminating in *z*, its capillaries; *y*, a minute bronchial tube, having a plexus, *m*, *m*, on its walls, from which that portion of the pulmonary vein which takes its origin from the plexus in the bronchial mucous membrane is derived. (Magnified 20 diameters.)

the pulmonary artery simply continues to divide again and again, giving off its branches on either side precisely as the bronchial tubes do. No sort of capillary distribution to any of the surrounding tissues is made in any part of its course; every portion of it reaches the ultimate leaflets of the lungs, and it does not give any branches of supply to any other portion: it makes no sort of anastomosis, either with its own branches or with any other vessels, until it reaches its final destination; and then the distribution of every individual portion of it is exactly alike, and that distribution is solely and entirely to the leaflets. When each bronchial tube spreads out into its final pedicels, the corresponding ultimate twig

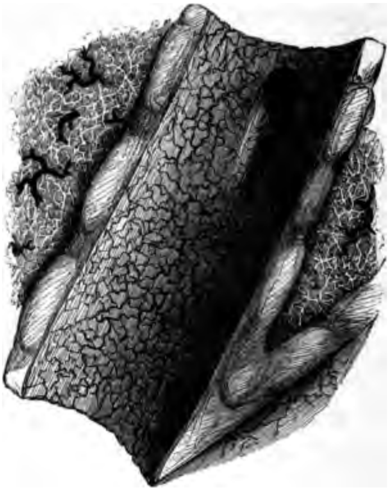


Series C, No. 2, fig. *b*, (sheep's lung,) shows the ultimate terminations of the pulmonary artery, *x*, and the commencement of the pulmonary vein, *m*; *y*, bronchial tube. (Magnified 3 diameters.)

of the pulmonary artery expands into a very remarkable reticulation. (*Vide* Series C, No. 2, fig. *a* and fig. *b*.) This reticulation is a meshwork of minute capillaries which anastomose in the most intimate manner; and this anastomosis is not confined to the meshes of each terminal twig of pulmonary artery, but there is likewise a close intercommunication between the capillary networks of adjoining leaflets: so that, like the bronchial tubes, the trunks of every subdivision of the pulmonary artery are kept wholly asunder and distinct until they arrive at their final distribution, and then the most equal and free intercourse is established between all the capillaries.

Formation and course of the pulmonary veins.

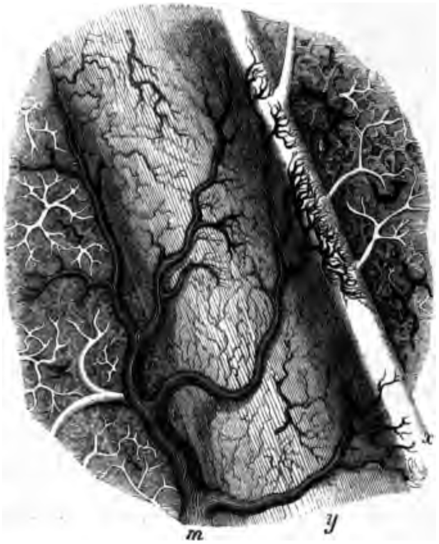
Having now traced the blood brought by the pulmonary artery, and having seen that every portion of it reaches the leaflets, and is there distributed in such a manner as to be suited to its fullest exposure to the atmosphere, but not in any degree so as to furnish any structure with its supplies for its repairs or construction, it remains to be seen in what way the blood (now become arterialized) is collected again into the veins which are to conduct it back to the heart. The arrangement by which this is done would be altogether as simple and unequivocal as the distribution of the artery, were it not that a diverticulum, as it were, of a part of the blood returning from the leaflets is made, whereby a portion of it undergoes a second application to the atmospheric influence previous to reaching the larger trunks of the veins, by being spread out in an extensive plexus, which is distributed over the bronchial mucous membrane. (*Vide* Series C, No. 3, fig. *a*.)



Series C, No. 3, fig. *a*, (sheep's lung,) shows the interior of a bronchial tube, with its mucous membrane minutely injected, in connexion with the pulmonary veins (magnified 10 diameters).

The feature which prominently attracts attention when examining a lung in which the pulmonary arteries and veins have been injected with different colours, is the fact that the mucous membrane of the bronchial tubes of every part of the lungs is of the same colour as that of the injection which has been passed into the pulmonary veins, and is not, like the remainder, made up of an equal admixture of capillaries containing both colours: so that if the pulmonary arteries have been perfectly injected with vermilion, and the pulmonary veins with chromate of lead, the mucous membrane will be decisively and uniformly yellow; and this yellow colour will be caused by the plexus which lines the bronchial tubes being fully injected by that fluid which entered the pulmonary veins; and if the colour of the injection has been reversed, then also the colour of the mucous membrane will be reversed, and the contrast will be as striking in the opposite way: the mucous membrane will then be uniformly red. It will be impossible to impart anything like the same depth of colour to the mucous membrane by any amount of injection by the bronchial artery, and it is only by the most complete injection possible of this latter artery that any vessels whatever in connexion with it can be made to show themselves in the mucous membrane at all; and then, those vessels will be of the minutest size imaginable, and have a distribution totally unlike and different from the proper plexus which is connected with the pulmonary veins. Both sets may, however, be made visible (as already remarked) in the same specimen, and then both are found to be entirely distinct; and it is evident, therefore, that they enter into no sort of anastomosis.

If the predominance of force in making the injections of the pulmonary vessels has been applied to the pulmonary artery, some of the coloured fluid injected into that vessel may have been made to pass through the capillaries distributed to the leaflets into the plexus which lines the mucous membrane; and then it can be made apparent that they are continuous with that plexus, which, however, is more nearly allied to the pulmonary veins, since the injection sent by the pulmonary arteries does not reach them until after it has passed through the capillaries of the leaflets. Still, this fact proves still more convincingly that this plexus exclusively belongs

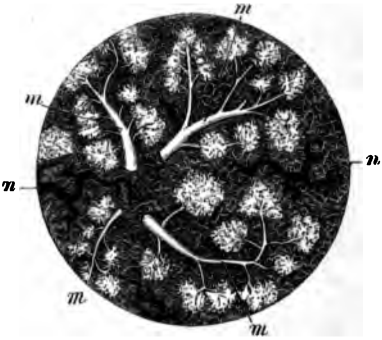


SERIES C, No. 3, fig. *b*, (sheep's lung), shows the ramusculi placed externally to the bronchial tube, which collect the blood from the plexus of the mucous membrane, and convey it to the trunks of the pulmonary veins (magnified 10 diameters).

to the pulmonary system. This plexus makes the only deviation from that which is perfectly simple and evident, in the arrangement by which the arterialized fluid is conducted by the pulmonary veins to the left auricle of the heart. Ramusculi, which are easily to be demonstrated, collect the blood from the plexus and pass it into the trunks of the pulmonary veins. These ramusculi are situated on the external surface of the bronchial tubes. (*Vide* Series C, No. 3, fig. *b*.)

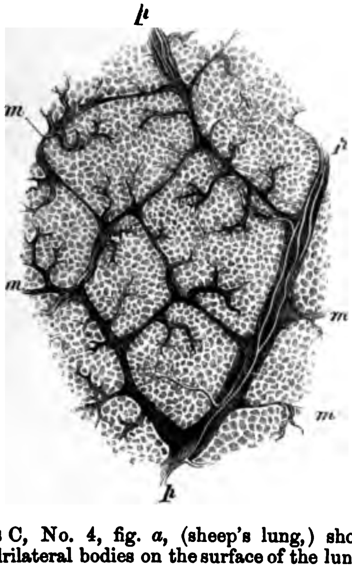
The plexus lining the mucous membrane is obviously a sort of diverticulum from the main current, by which the arterialized blood is returned to the left auricle of the heart, and is quite distinct and independent of any anastomosis whatever; it forms a much more vascular layer over the mucous membrane than could at all be attributed to the sustinent vessels, even if it could be shown that any portion of the distribution of these latter reached this plexus (while the contrary is proved beyond all possibility of dispute); and it may be fairly a matter of doubt whether, if the whole of the so-called bronchial arteries were exclusively confined to this plexus, and had no other distribution, they would be large enough to supply an equally vascular distribution to it. But it has been conclusively proved that the sustinent arteries are spread out in a very uniform degree to every part of the lungs; their principal distribution being to the *fibrous tissue* of the leaflets, and to the fibro-cartilaginous portions of the bronchial tubes.

Setting aside this diverticulum sent to the mucous membrane, and that portion which goes to the longitudinal channels of the pleura, the remainder of the anatomical characters of the pulmonary vein are as simple as possible. If a specimen be examined in which the pulmonary veins have been minutely injected with chromate of lead, it will be found that the pulmonary veins owe their commencement to little *tufts* of capillaries in the interior of the leaflets; and a difference will be observed in the character of the capillaries from which the veins take their origin, and of those in which the terminal pulmonary arteries are distributed: in the latter the reticulation is of an uniform and equal character, while in



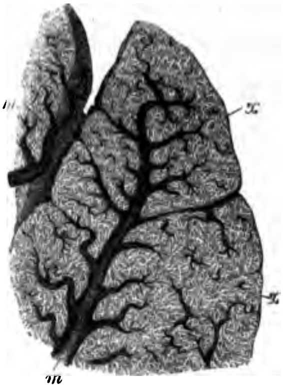
Series C, No. 3, fig. *c*, (sheep's lung,) shows the commencement of the largest portion of the pulmonary veins by tufts in the interior and on the surface of the leaflets. *m*, *m*, Tufts forming the origin of pulmonary veins; *n*, *n*, terminations of the pulmonary artery. (Magnified 20 diameters.)

the former they are collected in little knots or bundles, from which the minute pulmonary veins are seen to issue. It will be found also that there is in the upper surface of each lobule rather a more extensive ramification of the capillaries, directly continuous with the arteries; and that the minutest twigs of veins are arranged near the margins of each leaflet, and speedily dip down into the sulci between the leaflets, to form larger veins in the interlobular surfaces. (*Vide* Series C, No. 4, fig. *a.*) These continue to increase in size as they run in the interlobular spaces, where they are still placed in the fissures or crevices which

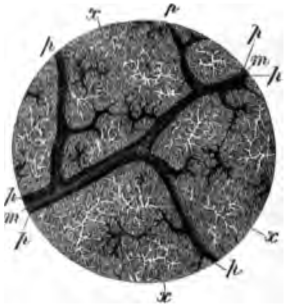


SERIES C, No. 4, fig. *a*, (sheep's lung,) shows the quadrilateral bodies on the surface of the lung, with the commencements of the pulmonary veins, *m*, *m*, dipping down between them. *p*, A fissure between two lobules. (Magnified 20 diameters.)

intervene between adjoining leaflets and lobules; and they collect twigs indiscriminately from all the lobules and leaflets among which they are placed. (*Vide* Series C, No. 4, fig. *b* and fig. *c*.) The blood, therefore, which they collect is not from any par-

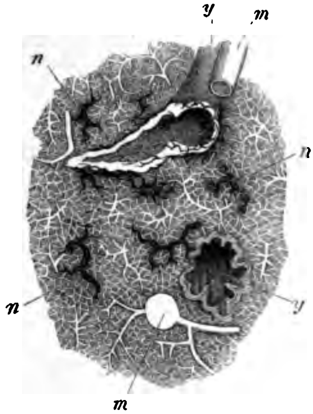


Series C, No. 4, fig. *b*, (sheep's lung,) shows the larger veins, *m*, *m*, on an uncut interlobular surface. They collect their tributaries indiscriminately from the adjoining lobules. *x*, *x*, Minute pulmonary arteries. (Magnified 10 diameters.)



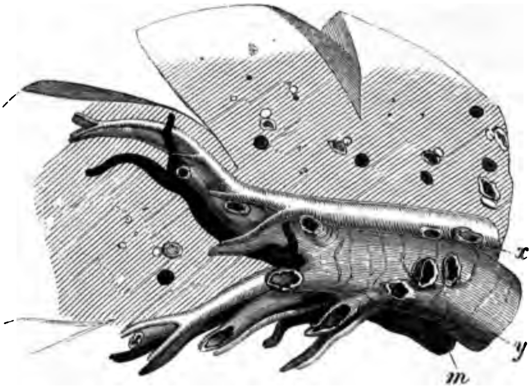
Series C, No. 4, fig. *c*, (sheep's lung,) shows the collection by the interlobular veins, *m*, *m*, of its tributaries from a cut surface. *x*, *x*, Pulmonary arteries; *p*, *p*, fissures between lobules, with pulmonary veins, *m*, *m*, running in them. (Magnified 30 diameters.)

ticular leaflet or lobule, but each leaflet and lobule sends its blood to more than one pulmonary vein. In this particular a very different arrangement prevails from that which governs the distribution of the pulmonary artery and of the bronchial tubes, previous to their arriving at that stage of their progress in which the pedicels are given off. The arrangement of the pulmonary veins is such as to favour the collection of the blood from as wide an area as possible; while that of the bronchial tubes and of the pulmonary artery, previous to the formation of its capillary network, is special and exclusive. (*Vide* Series C, No. 4, fig. *d.*)

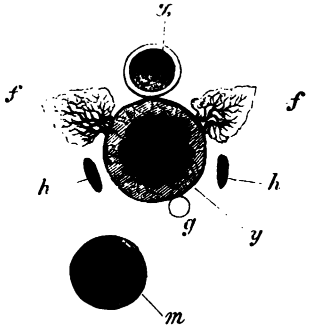


SERIES C, No. 4, fig. *d*, (sheep's lung), shows a cut surface of the injected lung. *y*, *y*, Bronchial tubes, with their rugæ and plexus; *m*, *m*, pulmonary artery; *n*, *n*, pulmonary vein. (Magnified 20 diameters.)

When the pulmonary veins which run in the interlobular spaces have attained a certain size, they soon come into contact with the bronchial tubes, and one of them becomes placed on the under surface of each tube, but still continues to run in an interlobular space. (*Vide* Series C, No. 5, fig. *a* and fig. *b*, and fig. *c*.) They collect similar branches from other lobules, and receive the trunks of the ramusculi which run on the outer

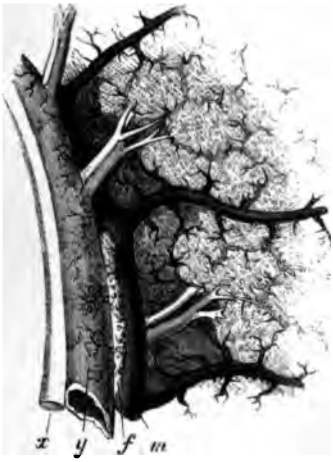


Series C, No. 5, fig. *a*, (sheep's lung,) shows the relative position of the larger trunks, taken longitudinally. *x*, Pulmonary artery; *y*, bronchial tube; *m*, pulmonary vein. (Diminished.)



Series C, No. 5, fig. *b*, is a diagram showing the relative positions of the trunks of the different vessels as seen in a transverse section. *y*, Bronchial tube with its rugæ; *f*, leaflets which cling to the bronchial tube and supply its plexus with blood; *x*, pulmonary artery (placed above the tube); *m*, pulmonary vein (placed below the tube); *g*, sustinent artery; *h*, *h*, sustinent veins.

surfaces of the bronchial tubes, and collect the blood from the plexus within them; and thus they continue to increase in size until they terminate in the four large veins which enter the left auricle of the heart.



SERIES C, No. 5, fig. *c*, is a diagram showing the principal features in the minute anatomy of the lungs. *x*, Pulmonary artery; *y*, bronchial tube with its ramusculi; *f*, leaflets clinging to bronchial tube; *m*, trunk of pulmonary vein.

In this course no branches of any sort or kind are given off from them to any structure whatever, and they receive no contributions from the bronchial vessels. Most certainly the blood brought by the sustinent arteries is not conveyed back (as some have asserted) to the heart in the smallest degree by these veins; otherwise there would be a small circulation going on round and round, through the left side of the heart, through the mucous membrane, *viâ* the sustinent arteries, and back to the left side of the heart, through the pulmonary veins: which hypothesis, though put forward in almost all modern anatomical works, would be entirely subversive of every physiological deduction that ever yet was made, or that ever could be made, and carries on the face of it its own confutation. If entertained, it would even negative the fact of there being such a thing as the circulation of the blood.

This current idea, that the arterial blood leaves the aorta by the so-called bronchial arteries in order to go again into the same system of blood-vessels in the lungs from which it has just taken its departure, is manifestly and glaringly untenable. It would be impossible to imagine that it should do this for no other purpose than that it might immediately come back to the same aorta in the self-same arterial state in which it was before, and that it should make this circuit for the purpose of accomplishing some change or function in the lungs, while itself undergoes no change whatever, or, if any, only such as would of necessity damage, *pro tanto*, its efficiency for the very purpose for which it was sent into the aorta at all.

All the above-mentioned postulates are obviously involved in the theory propounded in modern treatises, that in consequence of the assumed non-existence of special veins in connexion with the so-called bronchial arteries, the blood brought to the lungs by the latter vessels is restored to the circulation by means of the pulmonary veins.

CONCLUSION.

It would be superfluous in the present Treatise to cite the experiments and proofs which were many years ago communicated to the Royal Society, and subsequently reiterated in various publications, by which the fact of a galvanic current pervading the living blood, and generated by the action of the atmospheric oxygen on the venous blood in the lungs, was unanswerably demonstrated: because unless the case is already established by those evidences beyond all possible dispute, it would be an idle and useless endeavour to confirm the truth of any proposition whatever by ocular demonstration and by incontestable facts. It may, however, be incidentally remarked that the experiments of Professor Matteucci confirm indirectly and unwittingly the same conclusions. Whenever the thighs of frogs are prepared in the manner which he directs, so as to constitute a kind of voltaic pile, it invariably happens that the outer surfaces of the moist limbs become positively electric, while the interior, which are secluded from that influence, are negatively so. This arises from the direct action of the atmosphere upon the moist limbs of the dead frogs, and is in no respect due to the remains or dregs (so to speak) of the vitality which was once enjoyed by the living reptiles.

The muscular fibres which intervene between the internal and external portions in each limb—namely, that whereon the atmosphere exercises its influence, and that which is protected from its effects—being but an indifferent conductor, a certain amount of voltaic electricity *(generated at that very time by the atmospheric oxygen acting on the external surface)* is accumulated, and this again may be discharged by establishing the continuity of the galvanic circle through or across those intervening muscular fibres; and this can easily be done by using a metallic armature so as to join the two surfaces.

That those muscular fibres should contract when the galvanic current thus generated is discharged through them, is no more extraordinary than that they should do the same thing when a galvanic current generated in any other way is made to traverse through them, and does not at all prove the persistence of the same vital influences to which they gave obedience while the animal was living, and can no more be attributed to its vitality than the motions of a wooden toy which is made to jump on the floor by the ingenious application of beeswax and catgut can be assigned to the same cause.

That the muscular fibres should still be capable of contracting when acted upon by a particular physical cause, proves nothing more than that the contractile power still remains; and the same fact is shown quite as evidently in the elastic contractility belonging to the catgut strings of an ordinary musical instrument. Nobody, however, has yet had the presumption to attribute the harmonies elicited from the strings of Paganini's violin, in virtue of their elastic contractility, to the indwelling vital melody originally possessed by the animals from which those strings were made. This would be not one whit more preposterous than to identify the motions in a dead frog's legs, caused by a galvanic current generated at the time by an obvious cause, with the vitality possessed by the creature when it was a living and breathing animal.

Vitality is a galvanic force existing exactly during the time, and just so long and in proportion as the animal breathes, and not one instant longer. Its efficacy depends upon an uninterrupted circuit being established through the whole of the living blood; and this is the true import of the mechanical circulation of the blood: the meaning of the word *living* blood is comprised in this fact.

The mode in which the galvanic current is made to traverse the living blood may easily be understood by substituting a portion of the intestines of an ox or a sheep filled with salt and water, for the copper wires which are used as conductors in an ordinary galvanic battery: the conductors so constructed will act precisely in the same way as the copper wires would do in their action on the magnetic needle, and in electrolytic and electrotypic operations.

The blood contained in the larger blood-vessels exactly accomplishes this result with respect to the vital current which controls and gives force to all the functional operations of the animal body; the systemic capillaries being so many decomposing cells, governed by the primary current, generated by the action of the atmosphere on the venous blood in the lungs.

THE END.

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